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# Optimization of Variable Speed Wind Turbine Using Pi Controller

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## Abstract

***The paper presents an optimum design procedure for the controller used in the frequency converter of a variable speed wind turbine (VSWT) driven doubly fed asynchronous generator (DFAG) by using Proportional-Integral (PI) controller. The cascaded control is frequently used in the control of the frequency converter using the proportional PI controllers. The setting of the parameters of the PI controller used in a large system is cumbersome, especially in an electrical power system, which is difficult to be expressed by a mathematical model or transfer function. This study attempts to optimally design the parameters of the PI controllers used in the frequency converter of a variable speed wind energy conversion system (WECS). The permanent fault condition due to unsuccessful reclosing of circuit breakers is considered as well. It represents another salient feature of this study. It is found that fault-ride-through of VSWT-DFIG can be improved considerably using the parameters of its frequency converter obtained from PI controller.***

## Keywords

***Variable Speed Wind Turbine (VSWT), Doubly Fed Asynchronous Generator (DFAG), Wind Energy Conversion System (WECS).***

## 1. Introduction

In the process control industry, majority of control loops are based on proportional-integral (pi) controllers. The basic structure of the pi controllers makes it easy to regulate the process output. Design methods leading to an optimal and effective operation of the pi controllers are economically vital for process industries. Robust control has been a recent addition to the field of control engineering that primarily deals with obtaining system robustness in presences of uncertainties. in this thesis, a graphical design method for obtaining the entire range of pi controller gains that robustly stabilize a system in the presence of time delays and additive uncertainty is introduced. This design method primarily depends on the frequency response of the system, which can serve to reduce the complexities involved in plant modelling. The fact that time-delays and parametric uncertainties are almost always present in real time processes makes our controller design method very vital for process control. We have applied our design method to a DFIG model with a communication delay and a single area non-reheat steam generation unit.

The results were satisfactory and robust stability was achieved for the perturbed plants. conservation of non-renewable resources motivate to explore the new avenues of resources for electricity generation which could be clean, safe and most valuable to serve the society for a long period. The option came with huge number of hands up a source which is part of our natural environment and ecofriendly is the renewable energy sources. These sources can be better replacement of the polluted non-renewable sources in order to meet the growing demand for power due to rapidly growing economy and expanding population.

As per world energy outlook (weo)-2010 the prospects for renewable energy based electricity generation hinge critically on government policies to encourage their development. Worldwide, the share of renewable in electricity supply increases from 19% in 2008 to 32% in 2035 in the new policies scenario; it reaches only 23% in the current policies scenario, but 45% in the 450 scenario. in all three scenarios, rising fossil-fuel prices and declining costs make renewable more competitive with conventional hydropower has been the dominant renewable source of electricity for over a technologies. The recent strong growth in new technologies for wind power has created expectations among policy makers and the industry alike that these technologies will make a major contribution to meet growing electricity needs in the near future. it has also been forecasted that the increase in electricity generation from renewable sources between 2008 and 2035 will be primarily derived from wind and hydro power, which will contribute 36% and 31% of the additional demand respectively [1].

Wind power is projected to supply 8% of global electricity in 2035 up from just 1% in 2008. In the year 2010 the wind capacity has reached 196.630gw

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worldwide and it will reach 240gw by the end of 2011 as shown in fig 1[2].
In order to address the problem of rapidly growing demand for power, India has also taken its step forward along with other countries. Total power generation capacity is reached to173626.40mw. Out of the total capacity India's installed wind power generation capacity stood at about 13065mw as of march 2011.

## 2. Doubly-Fed Induction Generator Used In Wind Turbines

Most doubly-fed induction generators in industry today are used to generate electrical power in large (power-utility scale) wind turbines. This is primarily due to the many advantages doubly-fed induction generators offer over other types of generators in applications where the mechanical power provided by the prime mover driving the generator varies greatly (e.g., wind blowing at variable speed on the bladed rotor of a wind turbine). To better understand the advantages of using doubly-fed induction generators to generate electrical power in wind turbines, however, it is important to know a little about large-size wind turbines. This precludes the use of asynchronous generators in such wind turbines as the rotation speed of the generator is quasi-constant when its output is tied directly to the grid. This is where doubly-fed induction generators come into play, as they allow the generator output voltage and frequency to be maintained at constant values, no matter the generator rotor speed (and thus, no matter the wind speed). As seen in the previous section, this is achieved by feeding ac currents of variable frequency and amplitude into the generator rotor windings. By adjusting the amplitude and frequency of the ac currents fed into the generator rotor windings, it is possible to keep the amplitude and frequency of the voltages (at stator) produced by the generator constant, despite variations in the wind turbine rotor speed (and, consequently, in the generator rotation speed) caused by fluctuations in wind speed. By doing so, this also allows operation without sudden torque variations at the wind turbine rotor, thereby decreasing the stress imposed on the mechanical components of the wind turbine and smoothing variations in the amount of electrical power produced by the generator. Using the same means, it is also possible to adjust the amount of reactive power exchanged between the generator and the ac power network. This allows the power factor of the system to be controlled (e.g., in order to maintain the power factor at unity). Finally, using a doubly-fed induction generator in variable-speed wind turbines allows electrical power generation at lower wind speeds than with fixed-speed wind turbines using an asynchronous generator The power electronics devices used in doubly-fed induction generators, on the other hand, need only to process a fraction of the generator output power, i.e., the power that is supplied to or from the generator rotor windings, which is typically about 30% of the generator rated power. Consequently, the power electronics devices in variable-speed wind turbines using doubly-fed induction generators typically need only to be about 30% of the size of the power electronics devices used for comparatively sized three-phase synchronous generators, as illustrated in Figure.1. This reduces the cost of the power electronics devices, as well as the power losses in these devices.

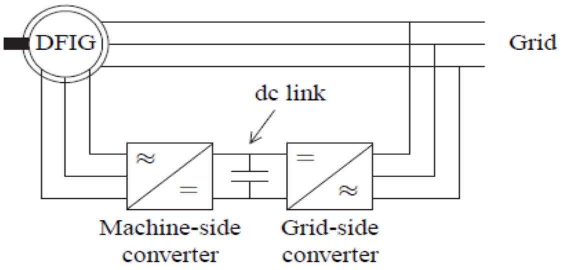

**Figure.1: DFIG system with a back-to-back converter**

## 3. Control Scheme Of The DFIG Control of Rotor-Side Converter (RSC)

The rotor-side converter (RSC) applies the voltage to the rotor windings of the doubly fed induction generator. The purpose of the rotor-side converter is to control the rotor currents such that the rotor flux position is optimally oriented with respect to the stator flux in order that the desired torque is developed at the shaft of the machine. The rotor-side converter uses a torque controller to regulate the wind turbine output power and the voltage (or reactive power) measured at the machine stator terminals. The power is controlled in order to follow a pre-defined turbine power-speed characteristic to track the maximum power point. The actual electrical output power from the generator terminals, added to the total power losses (mechanical and electrical) is compared with the reference power obtained from the wind turbine characteristic. Usually, [3] a Proportional-Integral (PI) regulator is used at the outer control loop to reduce the power error (or rotor speed error) to zero. The output of this regulator is the reference rotor current $irq_{ref}$ that must be injected in the rotor winding by rotor-side converter. This $q$-axis component controls the electromagnetic torque $Te$. The actual $irq$ component of rotor current is compared with $irq_{ref}$ and the error is reduced to zero by a current PI regulator at the inner control loop. The output of this current controller is the voltage $vrq$ generated by the rotor-side converter. With another similarly regulated *ird* and *vrd* component the required 3-phase voltages applied to the rotor winding are obtained. The generic power control loop is illustrated in the next section.

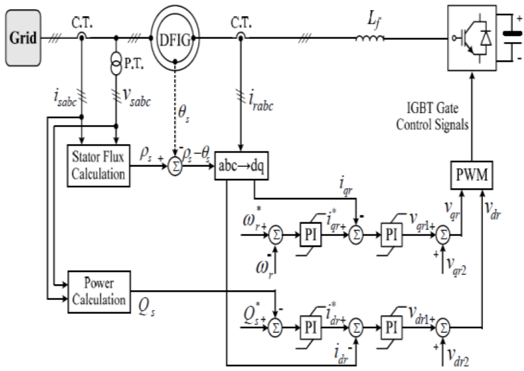

**Figure.2: Control scheme of the rotor-side converter**

## 4. Control of Grid-Side Converter

The main objective of the grid-side converter is to control the dc-link voltage. The control of the grid-side converter consists of a fast inner current control loop, which controls the current through the grid filter, and an outer slower control loop that controls the dc-link voltage. The reference frame of the inner current control loop will be aligned with the grid flux. This means that the *q* component of the grid-filter current will control the active power delivered from the converter and the *d* component of the filter current will, accordingly, control the reactive power. This implies that the outer dc-link voltage control loop has to act on the *q* component of the grid-filter current.

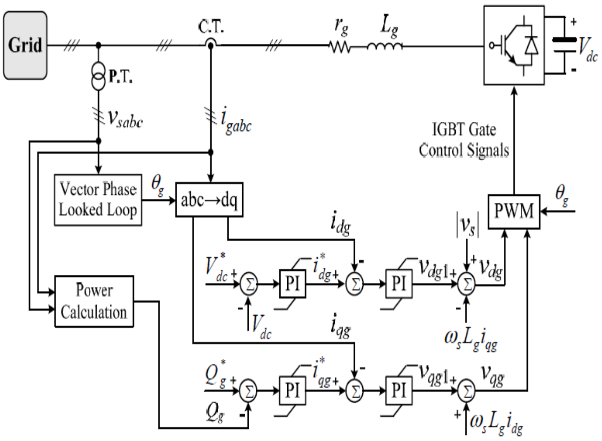

**Figure.3: Control scheme of the grid-side converter**

### a) Three-Phase Programmable Voltage Source

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics.

Use this block to generate a three-phase sinusoidal voltage with time-varying parameters. You can program the time variation for the amplitude, phase, or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

### b) The Three-Phase Mutual Inductance Z1-Z0

The Three-Phase Mutual Inductance Z1-Z0 block implements a three-phase balanced inductive and resistive impedance with mutual coupling between phases. This block performs the same function as the three-winding Mutual Inductance block. For three-phase balanced power systems, it provides a more convenient way of entering system parameters in terms of positive- and zero-sequence resistances and inductances than the self- and mutual resistances and inductances.

### c) The Three-Phase V-I Measurement

The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents.

The block can output the voltages and currents in per unit (pu) values or in volts and amperes. If you choose to measure the voltages and currents in pu.

### d) The Three-Phase Transformer

The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers. You can simulate the saturable core or not simply by setting the appropriate check box in the parameter menu of the block. See the Linear Transformer block and Saturable Transformer block sections for a detailed description of the electrical model of a single-phase transformer.

### e) The Three-Phase PI Section Line

The Three-Phase PI Section Line block implements a balanced three-phase transmission line model with parameters lumped in a PI section. Contrary to the Distributed Parameter Line model where the resistance, inductance, and capacitance are uniformly distributed along the line, the Three-Phase PI Section Line block lumps the line parameters in a single PI section as shown in the figure 2. where only one phase is represented.

### f) The Three-Phase Series RLC Load

The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

### g) Asynchronous Machine

The Asynchronous Machine block operates in either generator or motor mode. The mode of operation is dictated by the sign of the mechanical torque:
If Tm is positive, the machine acts as a motor.
If Tm is negative, the machine acts as a generator.
The electrical part of the machine is represented by a fourth-order state-space model and the mechanical part by a second-order system. All electrical variables and parameters are referred to the stator. This is indicated by the prime signs in the machine equations given below. All stator and rotor quantities are in the arbitrary two-axis reference frame (dq frame).

### h) Universal Bridge

The Universal Bridge block implements a universal three-phase power converter that consists of up to six power switches connected in a bridge configuration. The type of power switch and converter configuration is selectable from the dialog box.[4].The Universal Bridge block allows simulation of converters using either naturally commutated (or line-commutated). Power electronic devices (diodes or thyristors) and forced-commutated devices (GTO, IGBT, and MOSFET). The Universal Bridge block is the basic block for building two-level voltage-sourced converters (VSC) [5]. The device numbering is different if the power electronic devices are naturally commutated or forced-commutated. For a naturally commutated three-phase converter (diode and thyristor) [6].

## 5. Conclusion

The basic operation of DFIG and its controls using AC/DC/AC converter. The energy production of the DFIG wind turbine is investigated. The controller uses the DFIG equations to calculate the required rotor voltages in order to the active and the reactive power values reach the desired reference. The power control scheme helps the protection of rotor-side converter because there is no overshoot in the rotor current. Constant converter switching frequency is achieved that eases the design of the power converter and the ac harmonic filter.

The impact of machine parameters variations is analysed and found to be negligible due to the fact that in the deadbeat controller formulation the model errors was treated as a disturbance to the output control , operating conditions and variations of machine parameters. The DFIG is able to provide a considerable contribution to grid voltage support during short circuit periods. From the results it can be said that doubly fed induction generator proved to be more reliable and stable system when connected to grid side with the proper converter PI controller.

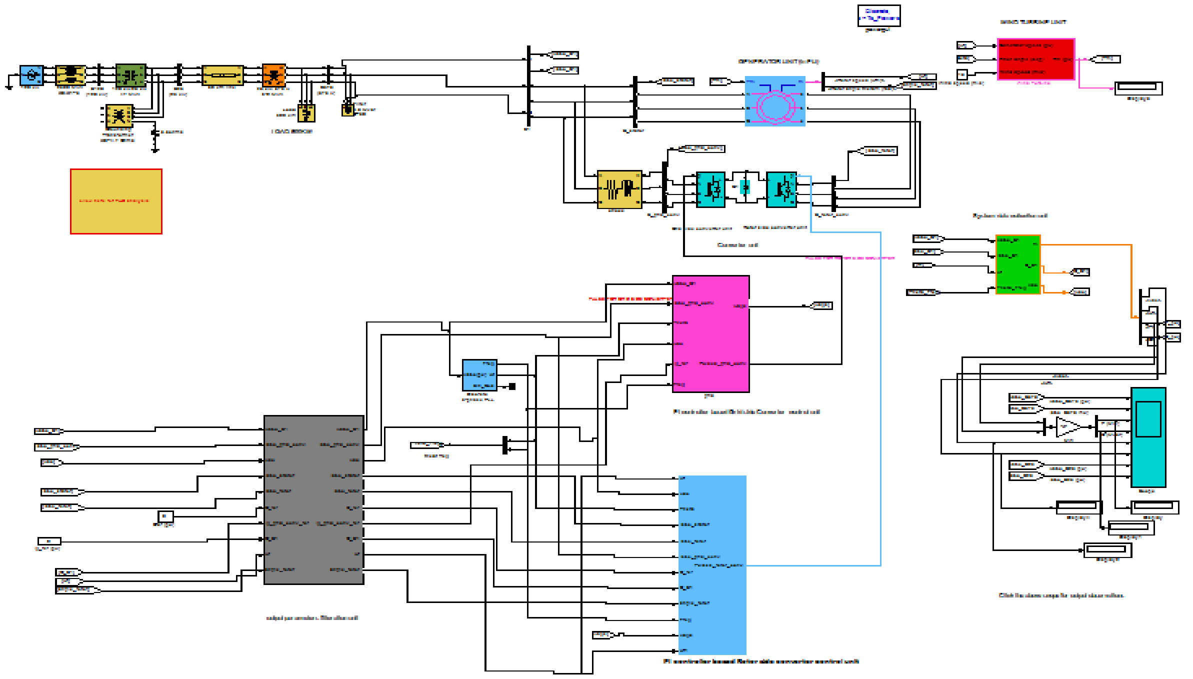

**Figure.4: Simulation Circuits**

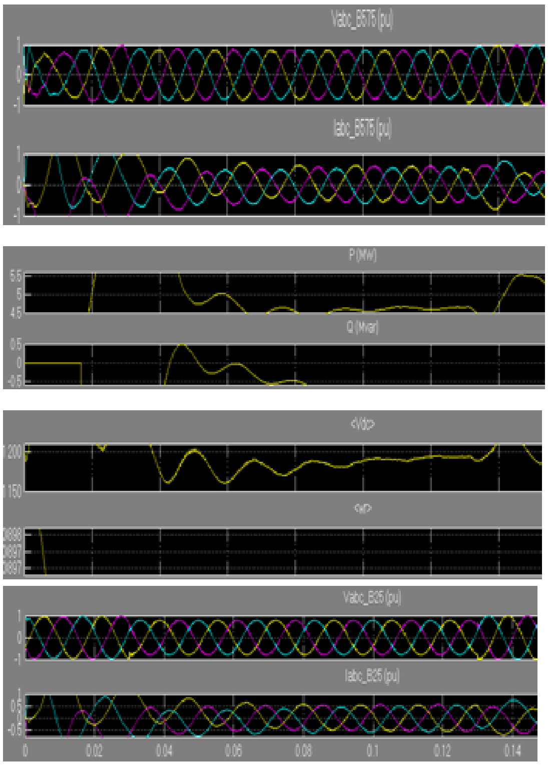

**Figure.5: Simulation Result**

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